

## INTEGRATION OF GIS BASED DECISION SUPPORT SYSTEM FOR MANAGEMENT OF OPERATIONS AND MAINTENANCE OF WATER NETWORK

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### ABSTRACT

GIS and DSS are used for management of water resources and to identify the relationship between GIS & DSS and used this relation as the base for studying how to use this relationship in the field of maintenance and operation for water networks systems. The research related to study the O&M system for Water Distribution System (WDS) by applying GIS with hydraulic modeling in creating O&M system for water distribution system. The study discusses one of the most existing important technology (GIS & DSS) for managing O&M which occupy the first level in database technology around the world. The aim of this paper is to improve the efficiency and performance for water pipes networks to improve the services for the population. All that done by establishing methods for the management of O&M system for water distribution systems using GIS & hydraulic modeling based on DSS. This will help the manager to select the best decision to managing water networks. The proposed systems for O&M which established in this thesis can be used by Municipality which carries the responsibility for managing water networks services in area.

**KEYWORDS:** GIS, DSS, Hydraulic, O & M, Water Network, WDS Etc

### INTRODUCTION

A WDS is a distributed system consisting of a set of links and nodes. The physical junctions of the pipes, points of any changes in linear pipes, reservoirs, and tanks are generally known as nodes, whereas all the pipes, valves, and pumps are considered links. Due to the continuous changes in friction coefficients, nodal demands, and reservoir water levels, it is very difficult to predict those parameters. Because of the semi-quantitative nature of the independent parameters, the simulated WDS dependent parameters (i.e., pressure at nodes and flow in pipes) are subjected to uncertainties. Today, in general most of the urban areas in the state as well as the country water supply are based on a piped system. These pipelines are generally 40-50 years old, in some places these may well be 70-80 years old. Although, over a period of time with the increasing demand this system has been extended and improved, yet it comes across that a lot of areas have old and leaking pipelines and many others have not been covered by piped water supply.

To study the existing water distribution system in municipality area, interview is made with head, manager, and water networks operators to clarify WDS and describe O&M system which the municipality depend on for management of water networks. All the data in the following paragraphs which is clarified the existing WDS & the existing O&M is related to interview with head, manager, and water networks operators. The reason behind that can be referred to;

- The old pipe network system.
- The illegal connections without any monitoring or control.

The water facilities is composed of main transmission pipes, distribution pipelines, ground water storage tanks, wells, booster pump stations and control valves. All these components comprise the water distribution system. This is due to the insufficient water infrastructure and water sources. Intermittent water distribution systems are water networks that

operate at specific time intervals i.e. not continuous.

A DSS <sup>2</sup> is a computer-based information system that supports either a single decision-maker or a group of decision-makers when dealing with unstructured or semi-structured problems in order to make more effective decisions. The DSS supports one or more decision-making activities carried out in a decision process. A DSS <sup>1</sup> primarily supports managerial activities at various levels. The purpose of a DSS <sup>4</sup> is focused on improving the effectiveness of the decision-making process, rather than its efficiency. The effectiveness of decision-making concerns timeliness, accuracy, and quality.

### **DSS Integrated Components<sup>6</sup> are**

#### **Data and Information Management**

The data and information component is key and central in developing a DSS. The focus is integrating database and connecting data islands into a dynamic framework with advanced display, mapping, query and presentation capabilities.

#### **Analysis and Modeling**

The data framework provides the basis for further analysis and interpretation of data and information. Depending on stage and scope of the DSS the analysis can range from simple to complex including statistical and numerical models, economic and cost/benefit as well as User Defined and Custom tools.

#### **Scenario Management and Alternative Formulation**

The DSS framework is capable of supporting and providing information (costing and prioritization) for project feasibility and planning projects as well as design and implementation. Upon implementation the project may have an operations component that requires real time and online decision making.

#### **Decision Making**

Customizable GIS and interfaces are tailored to meet specific needs and requirements. Advanced graphics, on-line access, custom rules and interpretations can be embedded into the DSS to support and provide the basis for decision makers to make timely, reproducible and well informed decisions.

These components integrate<sup>2</sup> and provide information to formulate the decision logic of the DSS. Rules and interpretations are embedded into the DSS to support and provide the basis for definition of problems and objectives. Decision support systems are frequently build within the framework of a Geographical Information Systems (GIS), which provide a convenient platform for handling, compiling and presenting large amounts of spatial data essential to water distribution management. Since GIS technology is often linked to information and knowledge management systems and is readily available to most governmental entities, a high degree of transparency in decision-making for stakeholders can be achieved.

In managing water distribution assets<sup>3</sup> (water, pipes, valves, connections, etc.) water utility agencies need to implement asset management strategies, alongside operations and maintenance methodologies that improve on a system's reliability and cost-efficiency. To that effect, an integrated pipeline asset management system is of high importance. The described integrated system and the lessons learned from its implementation are in essence a knowledge-based system, complemented with analytical and numerical analysis tools and supplemented with a geographical information system

(GIS) for the delivery to water distribution network owners and administrators of a complete decision support system<sup>6</sup> (DSS) that can help them improve on the management of the water distribution networks.

A GIS makes use of geographical and attribute data. Attribute data, addresses, populations, etc., is associated with geographical data. Geographical data may be represented as points, lines or polygons. Attribute data can be handled easily using a conventional database management system (DBMS). It is the handling of the geographical data, such as the existence of rivers, roads or contour lines that requires the use of the special techniques that characterize the use of GIS. A GIS<sup>5</sup>, as distinct from a mapping program, will have a database of geographic data, allowing linkages between different types of data and the ability to query this spatial data.

## MATERIALS AND METHODOLOGY

### Data for Water Supply Network Management

Information needed for managing a water supply network has different nature<sup>4</sup>. Though, it could be gathered in three main groups depending on its origin and its later usage. These groups are, basically, infrastructure information, customer's information and geographical information about both infrastructure and customers<sup>5</sup>. Traditionally, this information has been saved in different formats. In any case, rarely a connection among the three information sources existed. Next, a brief overview of the information involved in the creation of new pipes is presented

#### GIS Element Data<sup>1</sup>

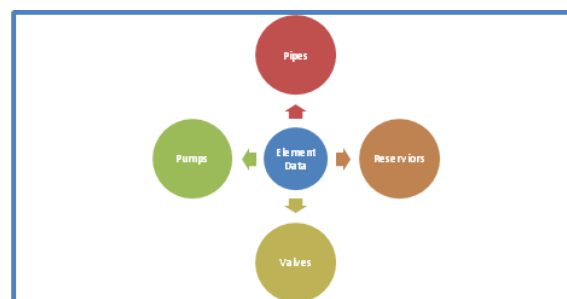
The information about network elements includes basically:

**Pipes:** diameter, length, date of installation, material, roughness; and leakage and maintenance history.

**Pumps:** number of pumps in the pumping station and pump curve or pumps characteristics.

**Valves:** diameter, minor losses coefficient, material, type of valve (ball, butterfly, angle, etc.) and type of operation (throttling, pressure reducer, check valve, etc.).

**Reservoirs:** shape, number of compartments, elevation, volume and connections.



**Figure 1: GIS Element Data**

This information was usually saved in work plots or small inventory databases. The main problem with this information was that in most of the cases, the graphic information was separated from the numeric data of each element.

The first step in its modernization was the use of relational databases for the alphanumeric data and Computer-Assisted Design (CAD) systems for the network plots. But this data structure is usually thought just as an inventory management without considering a future use in the model creation. Often there is no information on topology or connectivity other than the mentioned work plots.

Next, the graphic information was linked to the alphanumeric data through the AM/FM systems. The main developments in Water supply system (WSS) modeling have been based on this type of data management.

Using GIS in the management of the network will allow combining connectivity and infrastructure information. Other kind of element information is the operation data, that is, measurements made on the network which allow automated control of certain devices of the water system. This has been traditionally made by the Supervisory Control and Data Acquisition (SCADA) systems.

### **Consumption Data**

The economic information was the most carefully kept database in the system, where all the consumers relating data were recorded: their demands, addresses, registering date and other relating data for a correct economic management of the system. In fact, in most of the WSS there is some Customer Information System (CIS) used mainly for demand accounting and customer billing.

However, there was no further information on the demand location other than the customer's address. This has been one of the most developed items in the use of GIS within the WSS management. In fact, CIS contains customer consumption data that are essential for network modeling. Besides, knowing its geographical location will allow getting short and medium term estimation of future demands. Probably, this is the main challenge for the users of GIS in water supply systems. Combining consumption data with infrastructure and geographical location will allow automatic model creation from the GIS, including the load allocation of the model. GIS arise from the possibility of advising the customer in case of service interruption due to maintenance operations.

### **Spatial Data**

Finally, spatial<sup>7</sup> information was usually scattered in various topographic and thematic maps. Some of the attributes, which appear in those maps<sup>3</sup> are:

- The elevation contour lines of the supplied geographic area.
- The location of the reservoirs, mains, distribution pipes and the control devices of the network.
- The land uses map.
- The rest of the urban infrastructures layout.
- However, most of the times this information is not updated. Even though it is possible that some of the data above does not exist in graphic format.

All this information should be the base for the model creation and in GIS are used to be stored in various layers of information (Aslani, 2003).

### **Methodology for Integration of GIS & DSS for O & M of Water Network**

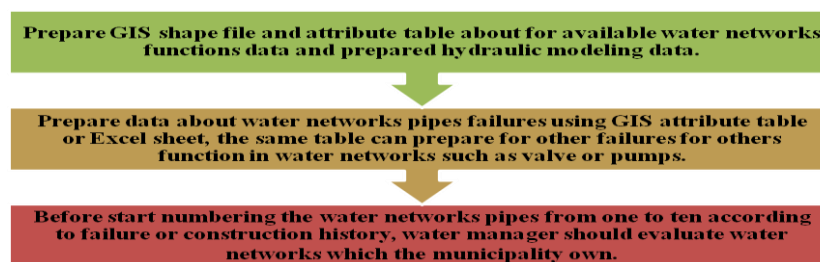
In order to manage maintenance and operation systems for managing water pipe networks pipe condition index proposed as a methods for manage water networks. The methods illustrate the effect of pipe condition, assumes the pipeline index from one to ten. The pipeline index means the condition of the pipeline, which number one represents the requirement for immediate repair and number ten expresses the new pipe. This number depends on failure history of pipes, types of pipes construction date, and diameters which refer the quantity and pressures which the pipe can bears it. And all of that depend on have attribute data about water networks which clarify all data

Of pipes and networks facility and ArcGIS which is the interface with EPANET is the best software selection help the manager to knowing water networks pipes situation.

For example Asbestos pipe should have number one which means must be replacement due to risk pollution cause by Asbestos material and effect on water which located in pipes. Pipe with low diameters and carry amount of water and pressure over loaded and has more than one failure also pipe condition index for it is one. Department manager can add the number for all networks according to knowing of history of water networks with assistance with his crews who are follow up daily operation and maintenance of networks.

Also by running the hydraulic model we can know the pipes which have pressure problem and these pipes can select by using GIS queries tools and have the pipe index numbers which mean there is decision should be done for it to solve this problem as we discuss below, another example can be mention by historical data of installation data of pipes and number of failure which is also can be indicate that is pipes needed to repair, replace or don't do any action for it according to pipe index numbers.

### Steps for Integrated Proposed Method to Find Pipe Condition Index

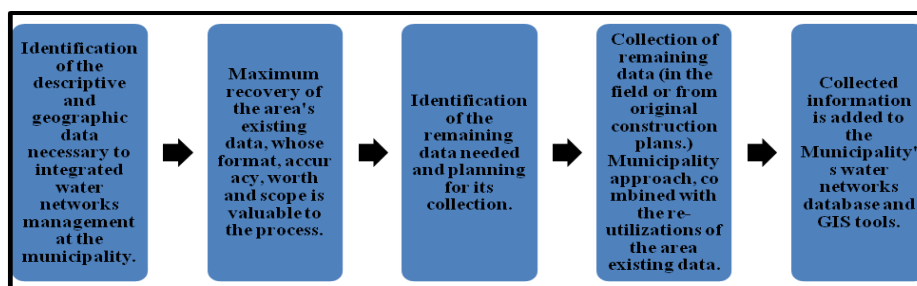


The evaluation steps can be divided into the following steps.

## RESULTS AND DISCUSIONS

### Collection Data about Water Networks which the Municipality Own

A complete water networks pipes inventory is the foundation of a structured management process<sup>15</sup>, allowing Municipality to proceed to the next step of the process, evaluation of the networks' condition and adding index numbers for pipe from one to ten This step includes the following:



### Evaluate the Condition of Water Network

In this step, a careful, field-verified gives a precise condition assessment of water network<sup>9,10</sup>. This step includes the following:

- The assessment is field-verified for accuracy.
- System parameters are adjusted for the results of field verification.

The following information describing the condition of water network, which should be added to the Municipality water networks database:

- Physical Integrity of the networks (Break History, Materials, & Water Loss).
- Functional Integrity of the networks (Hydraulic capacity, & Water Quality).
- Related network (Water Meter, & Valves).
- Socioeconomic impact (Claims, Duration of Repairs, & Traffic).

This process benefits on many levels. Municipality approach, combining its systems and close coordination with the water network area of internal and external resources, guarantees a precise condition assessment for each network. Field verification improves the definition of problem sectors, increasing savings in data collection.

A final condition assessment indicates the improvement status of water network segment:

**Table 1: Pipe Condition Index**

Status Water Pipe Network Segment	Pipe Condition Index
Imperative	1 to 3
Desirable	4 to 6
Segment to be Monitored	7 to 8
No Improvement Necessary	9 to 10

- Clarify the remaining service for water networks needed upgrade.
- Clarify and study available proposed solution for problem in water networks.

### **Practical Application Methodology<sup>19,20</sup>**

Using GIS is important to apply the decision. The following is a practical application for pipe lines replacement decision. The first step is to create Water Gems model. The benefit for this step is to get hydraulic model data such as pipes pressure & velocity and use this data as a tool for pipe condition index method.

### **Steps for Create Water GEMS<sup>17,18</sup> Model Inside Arcmap<sup>8</sup>.**

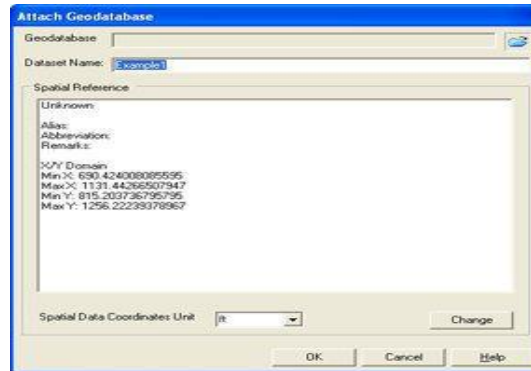
In the Arc Map Interface, the first step is to bring in the Water GEMS .wtg file. This is achieved using the following steps as shown in Figure 1

Click Bentley Water GEMS v8 - Project - Add Existing Project.



**Figure 2: Bring Water GEMS Data in Arc GIS**

- Next, select your .wtg file, and then attach a Geodatabase file as prompted in the new window that opens:



**Figure 3: Attach a Geodatabase in Arc Map**

- Input a new name for your new personal geodatabase, or browse to an existing geodatabase under Geodatabase field. Then, enter a new Feature Dataset name under the Dataset field. WaterGEMS v8 requires a geodatabase file to be specified as shown above. This geodatabase can be either a new or an existing Personal Geodatabase, but using a new Personal Geodatabase is recommended. This database file cannot be the WaterGEMS database itself (the .wtg.mdb file).
- Specify the appropriate units and click the Change button to specify or import a Spatial Reference. Click OK to bring your WaterGEMS model into the interface and create a new

Set of WaterGEMS Feature Classes in the Table of Contents area in ArcGIS<sup>11</sup>.

### Selection of the Pipe Lines to be Replaced

A certain criteria should be established by the decision makers to select replacement pipes. The selection depends on installation date of pipes, historical data about number of repair and failure, and quantity of water which this pipe feed the zones by it. Decision maker depend on GIS map and attribute tables data to get this information about the pipe line which selected to replace by use querying tools.

### Pressure Calibration

In this decision maker get data by GIS map, attribute table data, hydraulic modeling output which clarify the pipe line pressure data. GIS by querying tool scan clarify location and properties of pipes. The decision maker will be provided necessary information to decide the proper decision such as changing valve statues, replace some pipe lines, or installing a poster pump.

The proposed O&M system depends on the use of the integration between GIS and Hydraulic modeling based on DSS<sup>11 12</sup> for management O&M water networks to take the best decision at the needed time for all daily works.

### Benefits

- Using GIS and DSS in the proposed O&M system will assist the water networks department.
- Providing data base for water networks include shape files, AutoCAD file, and hydraulic modeling data which can minimize the human mistake.
- Help the water department to feed all zone by equal quantity of water for all customer by the proposal water distribution systems.
- Clarify the valves which control water networks.

- Provide a clear program for distribution water networks for all zones.
- Clarify water networks pipes and diameters.

## CONCLUSIONS

The goal of hydraulic model is to prepare the base data for operation department help us to manage water networks and prepare a good program for distribution zone, also knowing the location of control valves and zone which controlled by it, away for controlling water networks, knowing the pipes which have a pressure problem, and knowing the affect done in water networks systems such as pressures if there any change done in networks. Also out but result use as a guide for using pipe condition index method.

Proposed pipe condition index help the water department for assessing, current and future risk levels of a particular pipe and groups of pipes, investigating scenarios for risk reduction and cost efficiency of pipeline failure mitigation options, thus allowing for prioritization between pipeline replacement or pipeline management work packages, exploration of pipe asset and failure data, reporting capabilities allowing Water Utilities to quickly collect data for reports. Also if there is any failure in water networks pipes, and needed to close pipe zone and use other distribution pipe zone to feed other area by it we can by pipe condition index know if this zone can pipe can bear the quantity and pressure or not.

The proposed system saving time, effort, and cost by guarantee an immediate corrective action for the whole defects of the water distribution system component.

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